

Navigating E-906/SeaQuest on the (Fermi)Grid



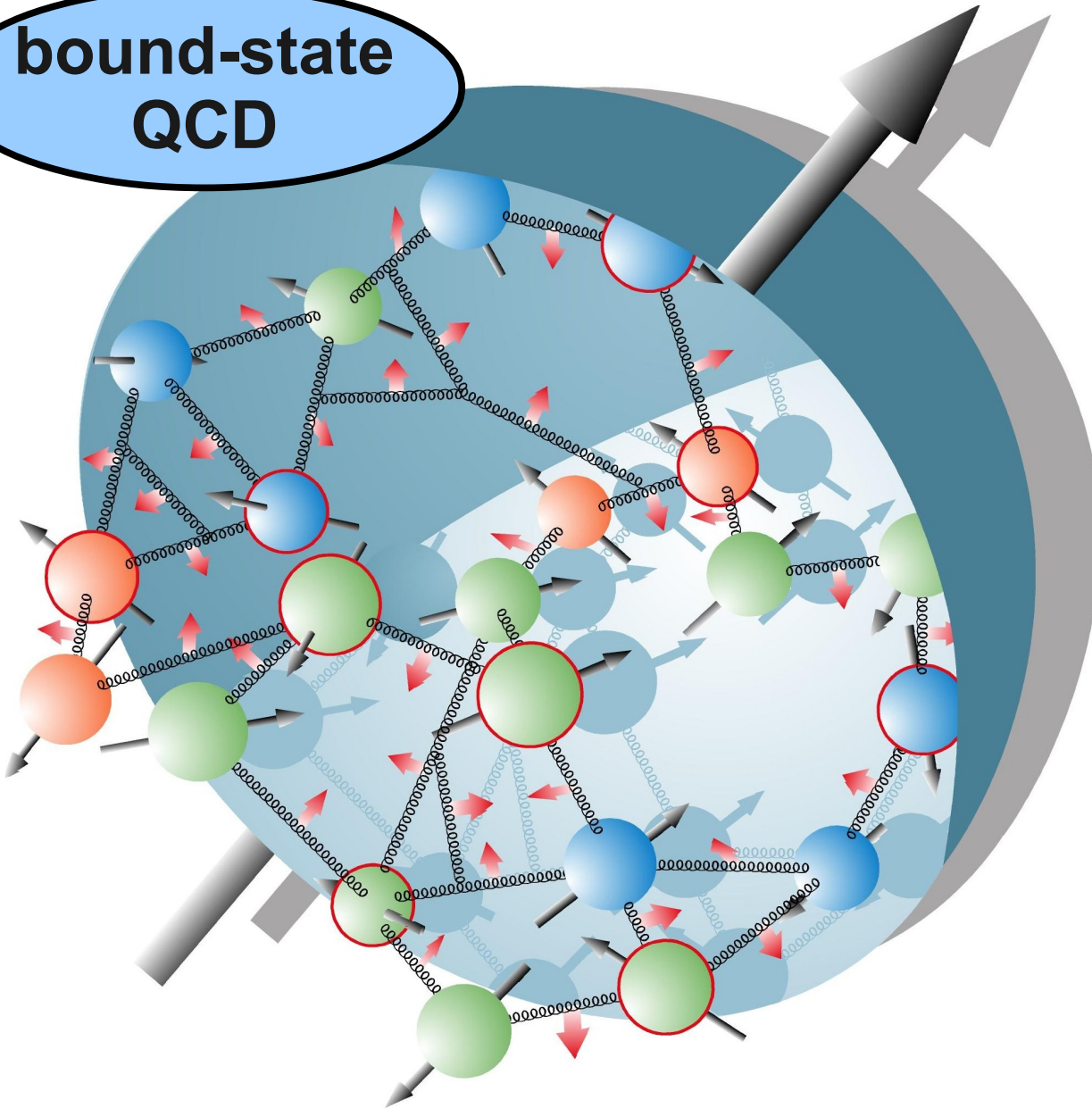
Markus Diefenthaler (UIUC)

The SeaQuest Collaboration

- **Abilene Christian University:** Donald Isenhower, Tyler Hague, Rusty Towell, Shon Watson
- **Academia Sinica:** Wen-Chen Chang, Yen-Chu Chen, Shiu Shiuan-Hal, Da-Shung Su
- **Argonne National Laboratory:** John Arrington, **Donald F. Geesaman** (*co-spokesperson*), Kawtar Hafidi, Roy Holt, Harold Jackson, David Potterveld, **Paul E. Reimer** (*co-spokesperson*), Joshua Rubin
- **University of Colorado:** Ed(ward) Kinney, Joseph Katich, Po-Ju Lin
- **Fermi National Accelerator Laboratory:** Chuck Brown, Dave Christian, Jin-Yuan Wu
- **University of Illinois:** Bryan Dannowitz, Markus Diefenthaler, Bryan Kerns, Naomi C.R Makins, R. Evan McClellan, Jen-Chieh Peng
- **KEK:** Shin'ya Sawada
- **Ling-Tung University:** Ting-Hua Chang
- **Los Alamos National Laboratory:** Christine Aidala, Gerry Garvey, Mike Leitch, Han Liu, Ming Liu, Pat McGaughey, Joel Moss, Andrew Puckett
- **University of Maryland:** Betsy Beise, Kazutaka Nakahara
- **University of Michigan:** Chiranjib Dutta, Wolfgang Lorenzon, Richard Raymond, Michael Stewart
- **National Kaohsiung Normal University:** Rurngsheng Guo, Su-Yin Wang
- **University of New Mexico:** Younus Imran
- **RIKEN:** Yoshinori Fukao, Yuji Goto, Atsushi Taketani, Manabu Togawa
- **Rutgers University:** Lamiaa El Fassi, Ron Gilman, Ron Ransome, Brian Tice, Ryan Thorpe, Yawei Zhang
- **Tokyo Tech:** Shou Miyaska, Kenichi Nakano, Florian Sanftl, Toshi-Aki Shibata
- **Yamagata University:** Yoshiyuki Miyachi

The inner structure of the nucleon

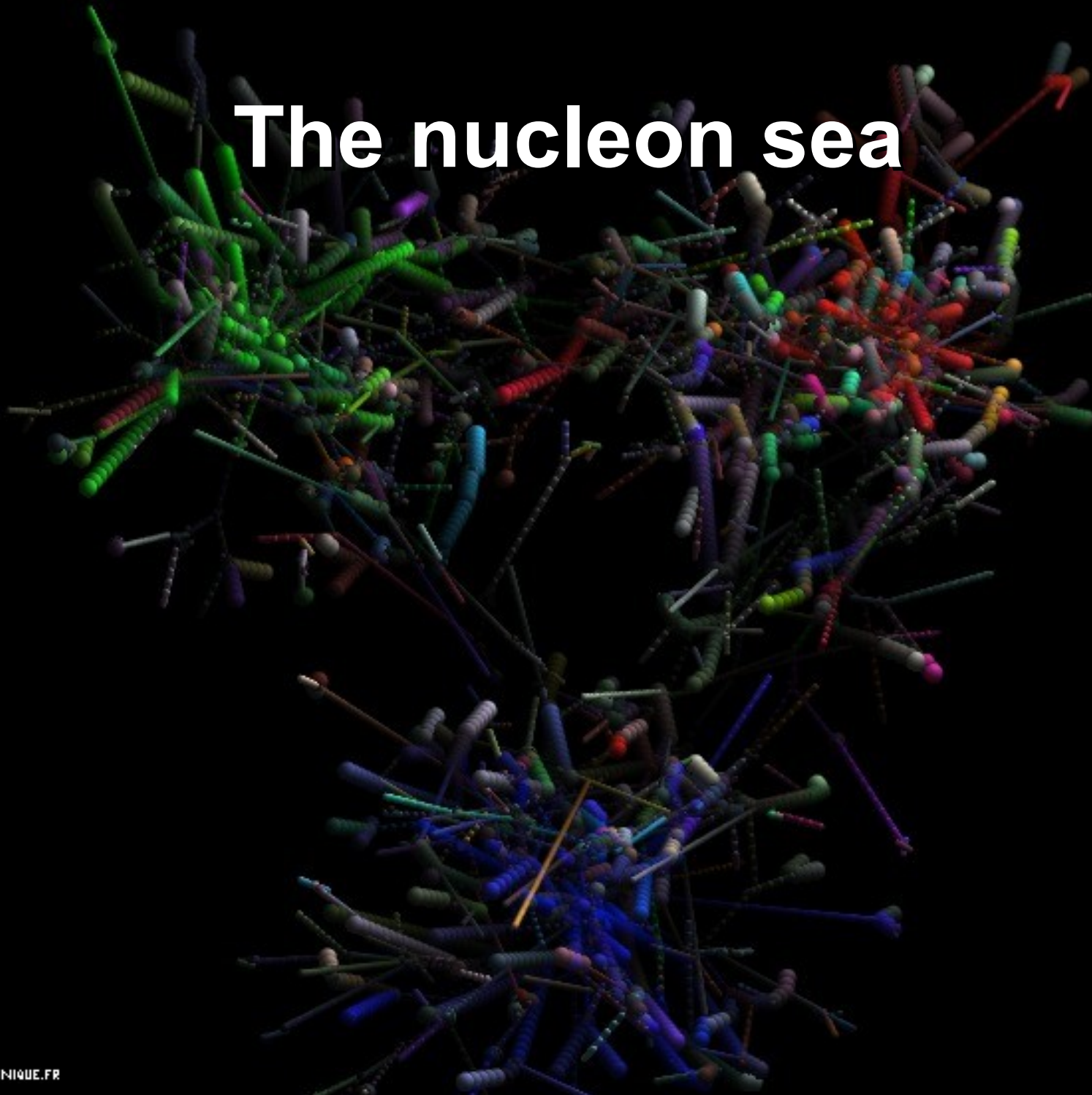
bound-state
QCD



Quarks $\text{spin} = 1/2$		
Flavor	Approx. Mass GeV/c^2	Electric charge
u up	0.003	$2/3$
d down	0.006	$-1/3$
C charm	1.3	$2/3$
S strange	0.1	$-1/3$

Strong (color) $\text{spin} = 1$		
Name	Mass GeV/c^2	Electric charge
g gluon	0	0

The nucleon sea



The inner structure of the nucleon

- Mathematical proof of confinement included among the seven Millennium Prize Problems in Mathematics.
- **Exploring the nonperturbative regime:**
 - **Lattice QCD:** *“Through difficult calculations of merciless precision that call upon the full power of modern computer technology, [...] they have demonstrated the origin of the proton's mass [...] I believe this is one of the greatest scientific achievements of all time.”* (Frank Wilczek)
 - Intense **experimental studies** of deep-inelastic scattering, electron-positron annihilation and proton-proton collisions (including **Drell-Yan scattering**).

Probing the inner structure

cross-section measurements

$$F_1(x, Q^2) = \sum_q e_q^2 \left(f_1^q(x, Q^2) + f_1^{\bar{q}}(x, Q^2) \right)$$

decomposed

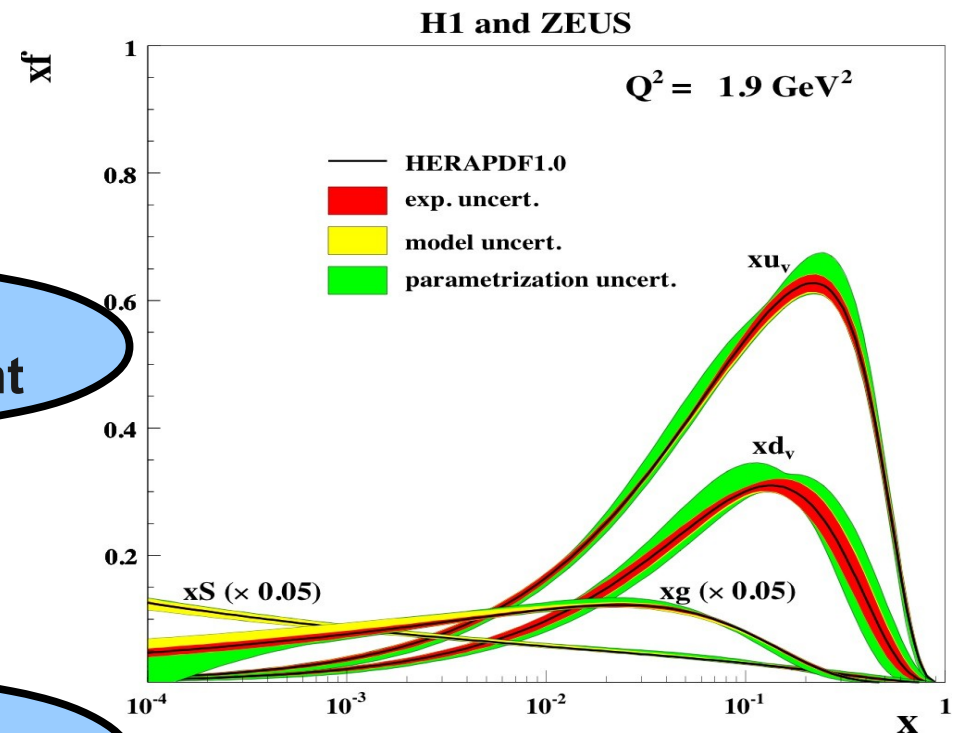
structure functions

process
dependent

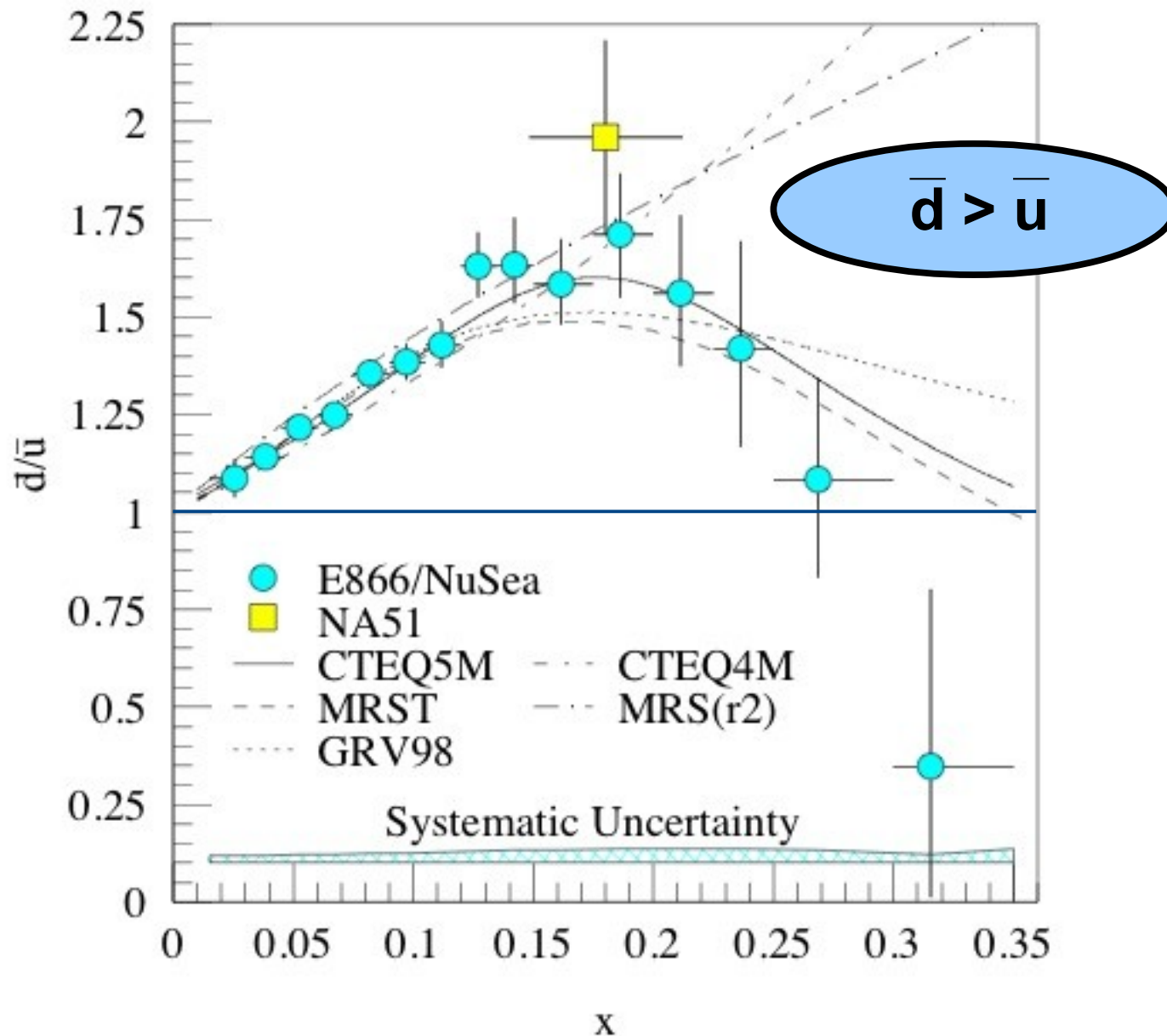
interpreted

Parton Distribution Functions

universal



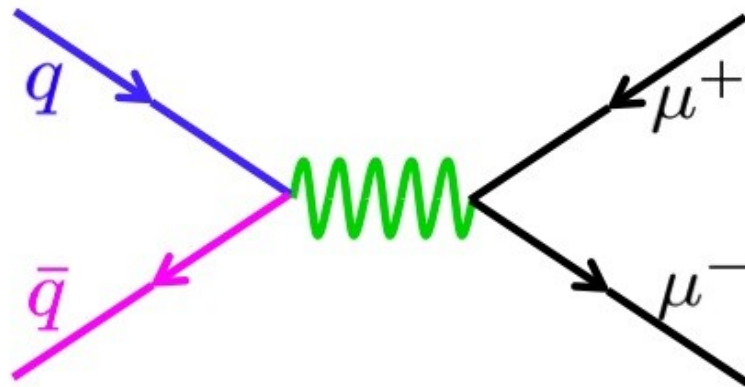
Insights into the proton sea



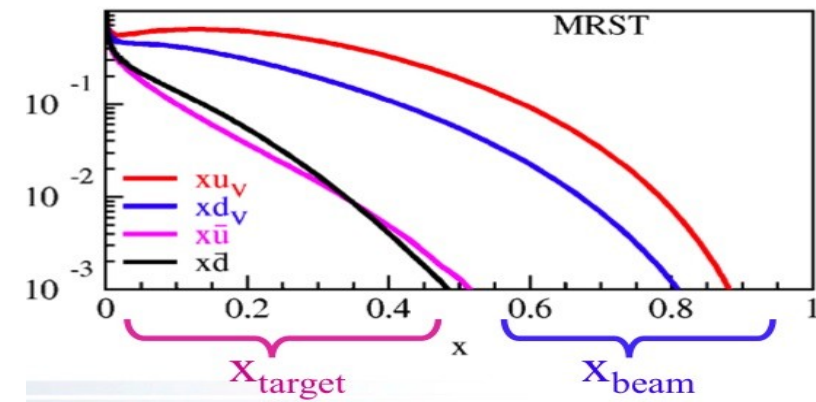
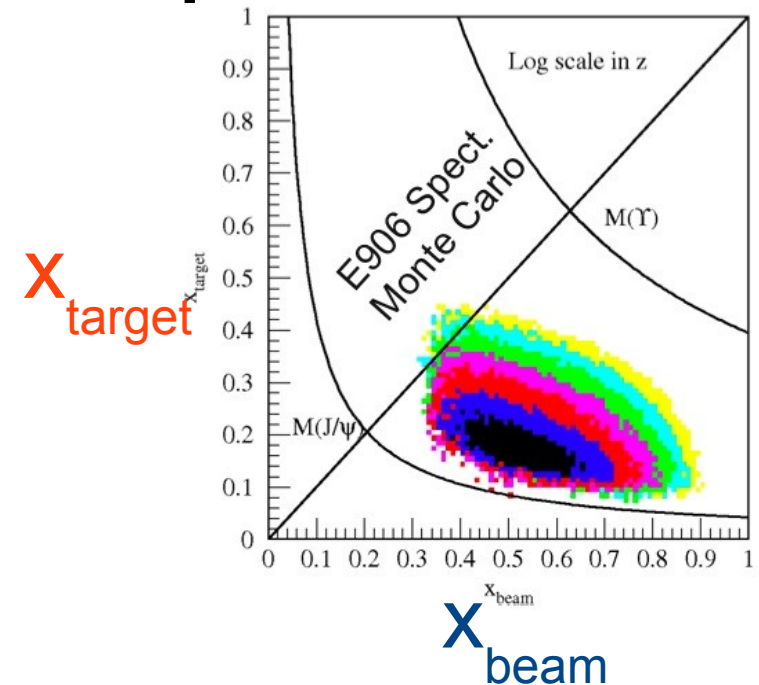
alternate degrees of freedom?

A laboratory for sea quarks

The Drell-Yan process

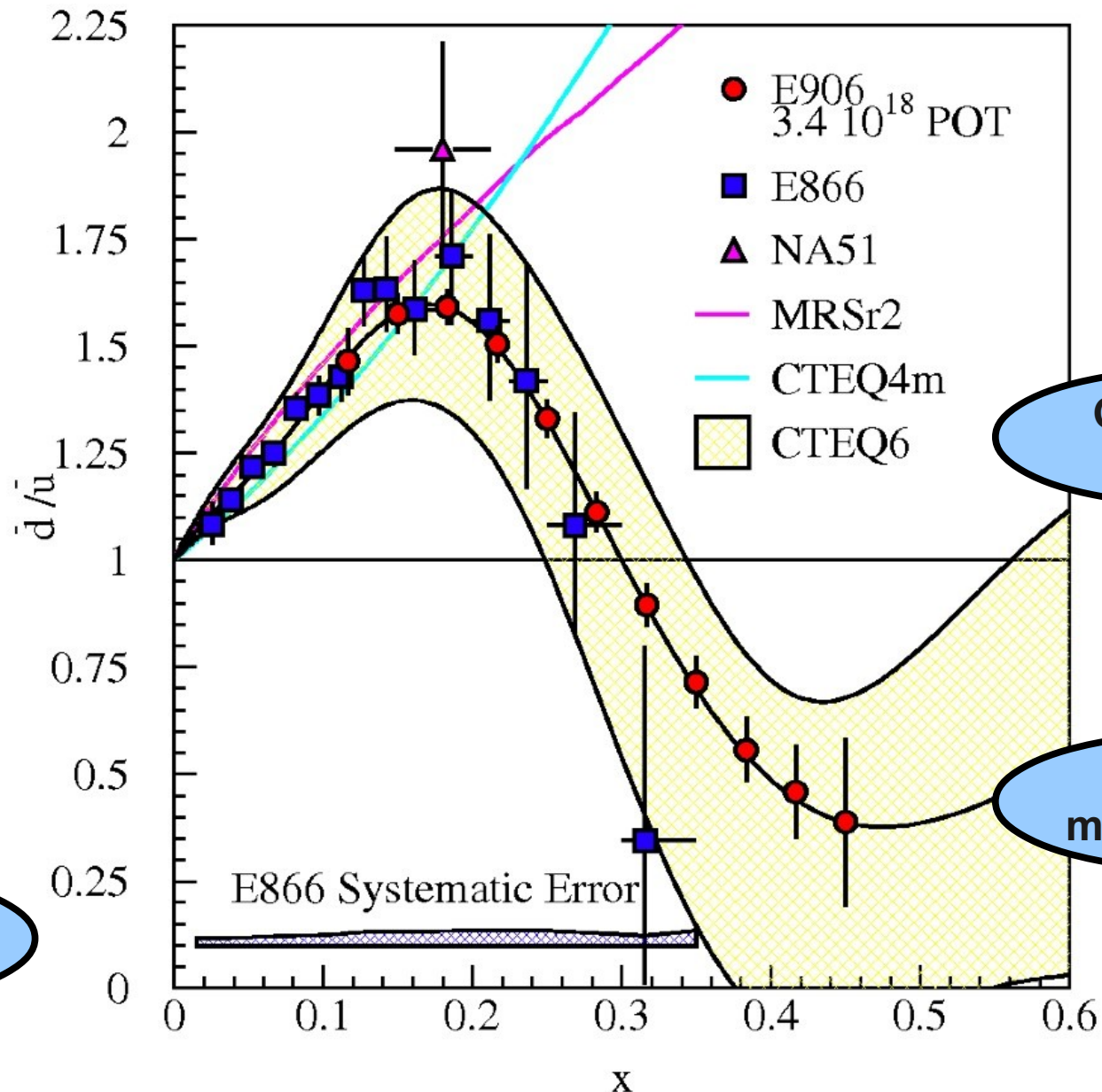


$$\frac{d^2\sigma}{dx_b dx_t} = \frac{4\pi\alpha^2}{9x_b x_t} \frac{1}{s} \sum_q e_q^2 [\bar{q}_t(x_t)q_b(x_b) + q_t(x_t)\bar{q}_b(x_b)]$$



beam: valence quarks at high- x
target: sea quarks at low/intermediate- x

SeaQuest probing the proton sea



SeaQuest:
Syst. $\sim 1\%$

The SeaQuest mission

- **significant increase in physics reach**
- unique access to **sea quarks at high-x**
- **What is the structure of the nucleon?**
 - What is \bar{d} / \bar{u} ?
 - What are the origins of the sea quarks?
 - What is the high-x structure of the proton?
 - How are quark spin and orbital motion correlated?
- **What is the structure of nucleonic matter?**
 - Where are the *nuclear* pions?
 - Is antishadowing a valence effect?
- **Do colored partons lose energy in cold nuclear matter?**

The proton beam for SeaQuest

- extracted from **Fermilab Main Injector**



- 2×10^{12} protons / s for 5s spills each minute
- **120 GeV** proton beam instead of a 800 GeV proton beam (as used for E-866 / NuSea):
 - Drell-Yan cross section scales as **1/s**
 - J/ψ decay (dominant background) scales as **s**
 - **50x** luminosity as E-866 (for same rate)

The SeaQuest target



luminosity:
 $3.4 \times 10^{35} / \text{cm}^2 / \text{s}$

liquid
hydrogen

liquid
deuterium

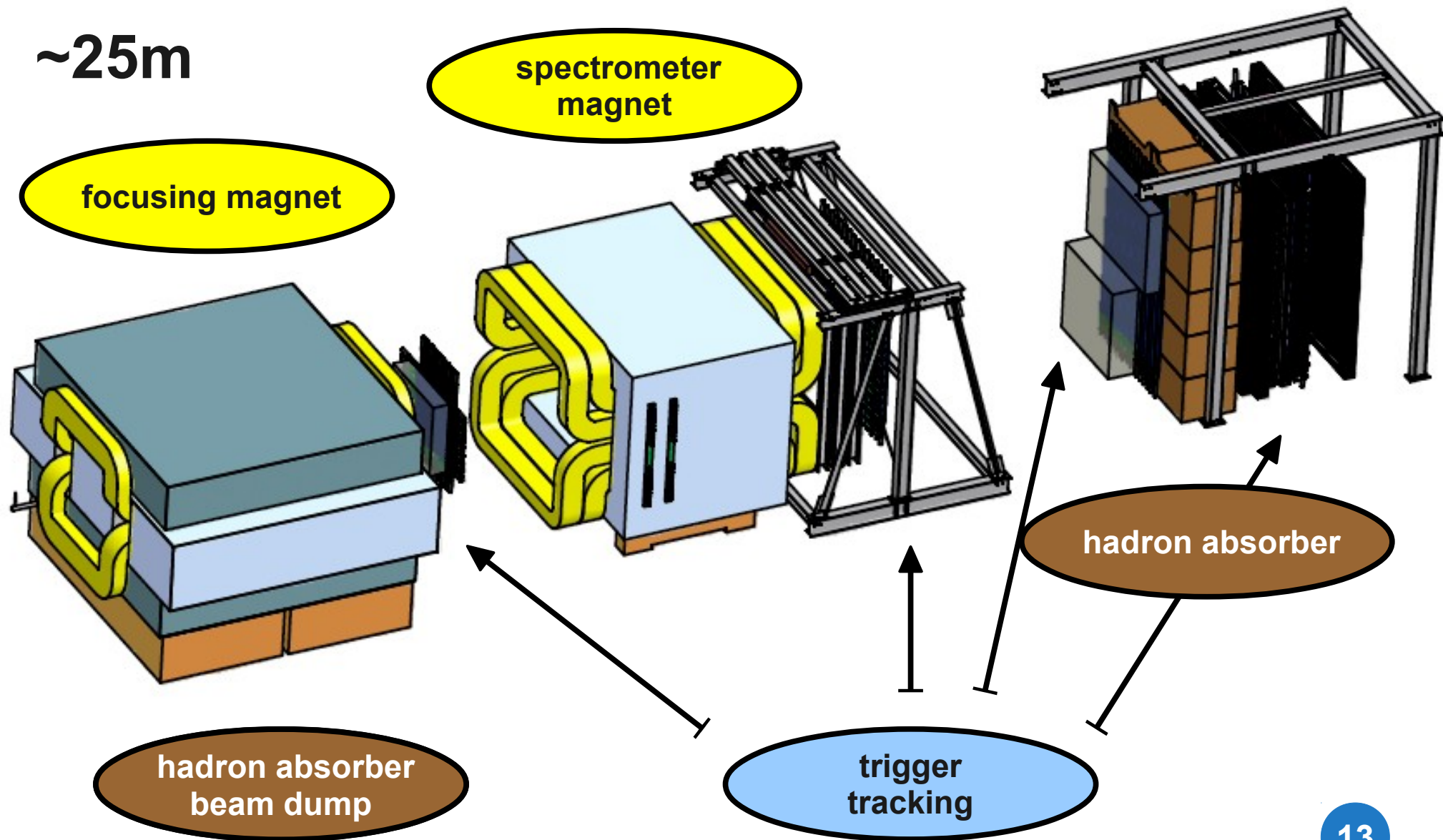
Carbon

Calcium

Tungsten

2012.02.23

The SeaQuest spectrometer



The SeaQuest Data

1) Coda:

event type (e.g. physics event)

VME

TDC

roclD boardID, channelID

encoded pulse:

0011 1111 1111 0000 01

details in the talks by Kaz & Grass

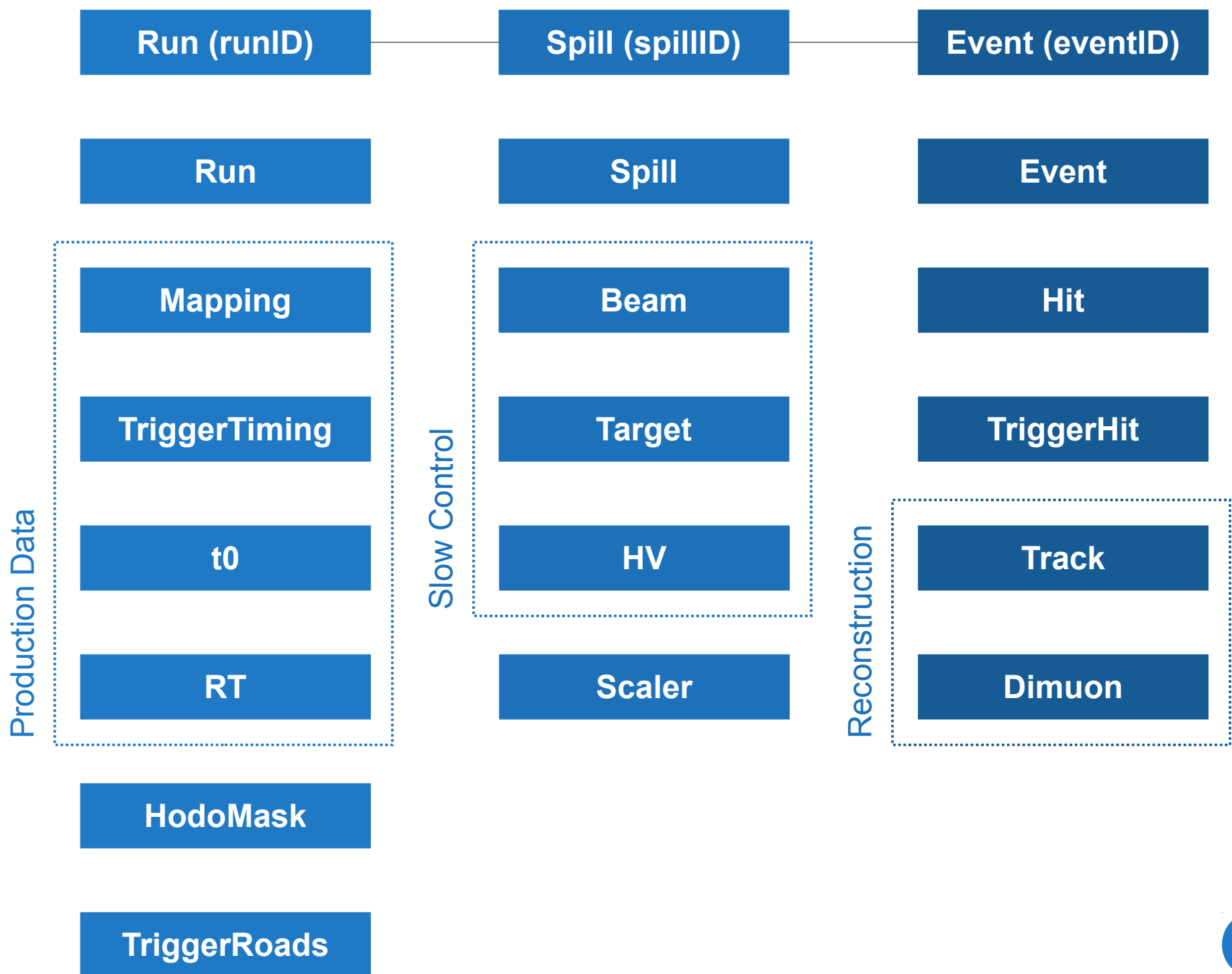
2) DeCoda + Production Data: detectorName, elementID tdcTime, signalWidth

3) MySQL: universal interface (C, C++, Perl, Python, ROOT, Excel, R SPSS, ...)

data-based analysis framework:

- combine best available knowledge
- data quality
- hodoscope masking
- track information
- dimuon information

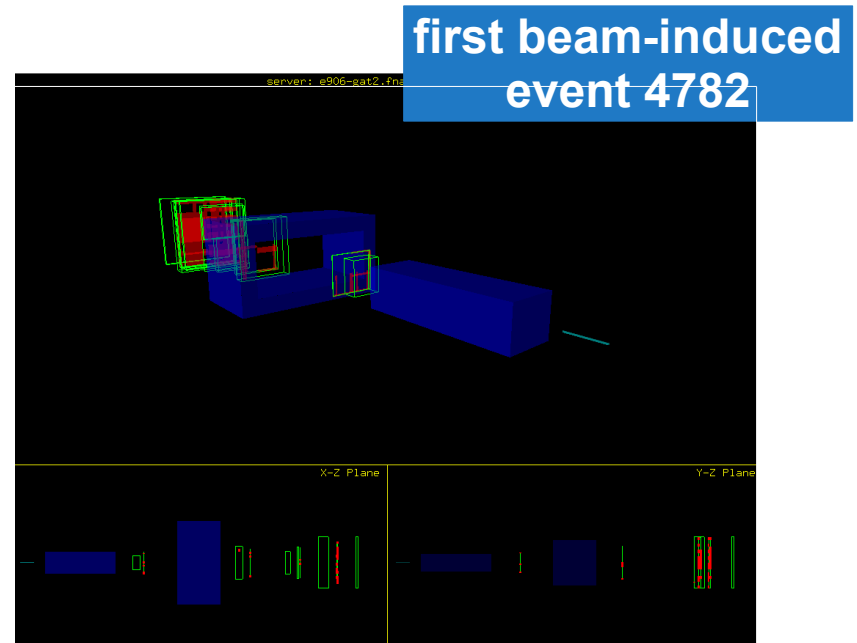
details in the talk by Bryan D.



Run I: 03/07/2012 – 04/30/2012

- In the **night from March 7th to 8th 2012**: “Joy and toil as Fermilab sends first particles to SeaQuest” (Fermilab Today)
- **Run 266** – first run of Run I

The rush of excitement and surprise in the room quickly turned to feverish studying, as the team scrambled to make sense of the data. The beamline, they discovered, was delivering small batches of protons that created about 10,000 muon particles per pulse to the SeaQuest hall, a sign that more adjustments were needed for a stable particle beam and for the experiment to begin taking data. (Fermilab Today)



- **Run 2173** – last run of Run I (00:01 April 30th 2012)

SeaQuest on the Grid

- subgroup of the "umbrella" FNAL virtual organization
- **FermiGrid** submission machine using jobsub
- **data productions (first step):**
 - binary file of raw data (CODA, O(1GB))
 - decoding framework in C and Perl
 - track reconstruction in C and C++/Root
 - reading calibration information from MySQL databases
 - writing to MySQL databases (O(3-5GB))
- **Monte Carlo productions (also in MySQL):**
 - GMC framework
 - custom event generators + Pythia8 (C++)
 - scalable
- **user jobs**

The background of the slide is an underwater scene. It features a deep blue color gradient, with lighter blue at the top where sunlight penetrates the water, creating visible light rays and a shimmering effect. The water appears slightly rippled, giving it a textured look.

**Many thanks to
Gabriele Garzoglio, Marko Slyz,
Dennis Box, Steve Timm!**